Muon Backgrounds

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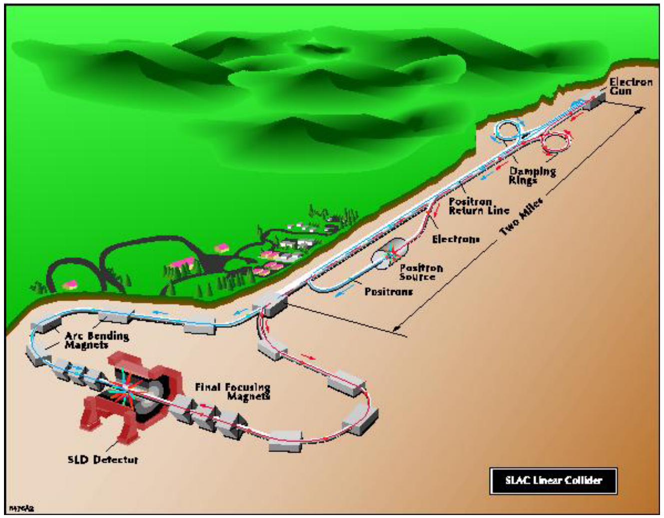
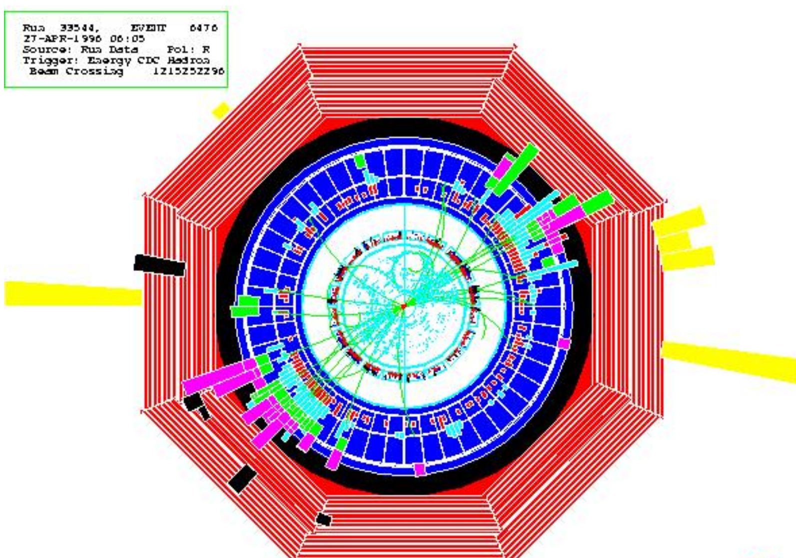
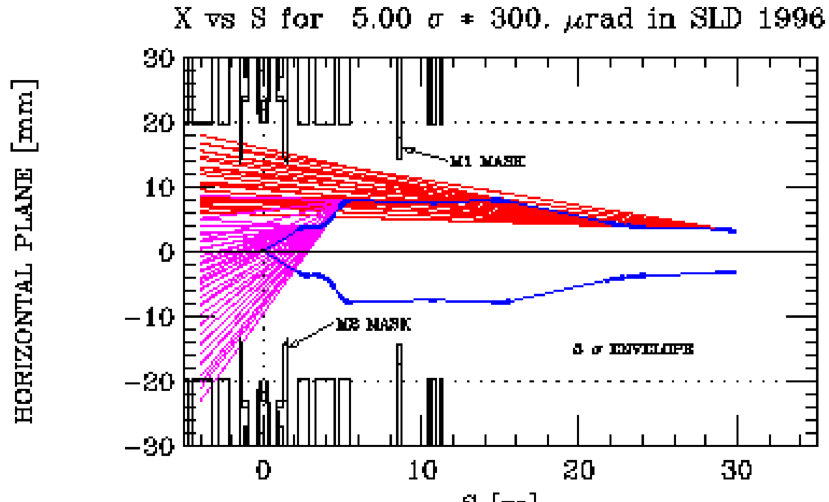
SLAC

Halo '03 Montauk NY
22 May 2003

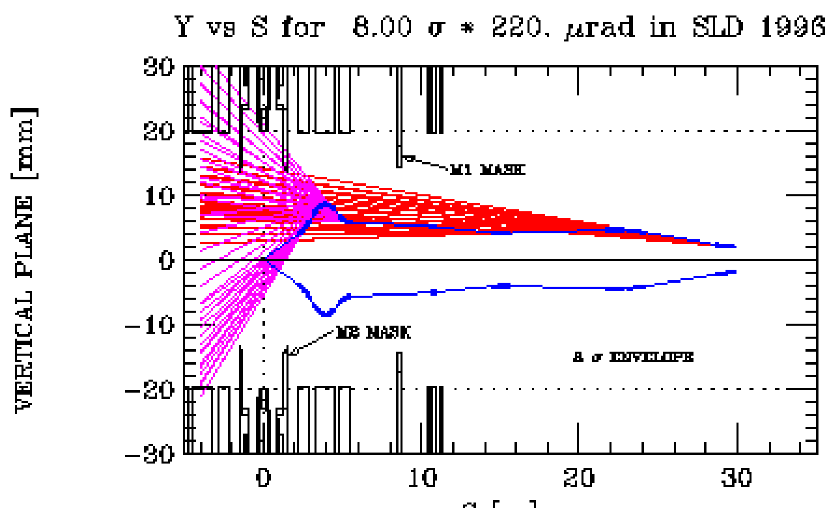
Historical Perspective
SLC and SLD





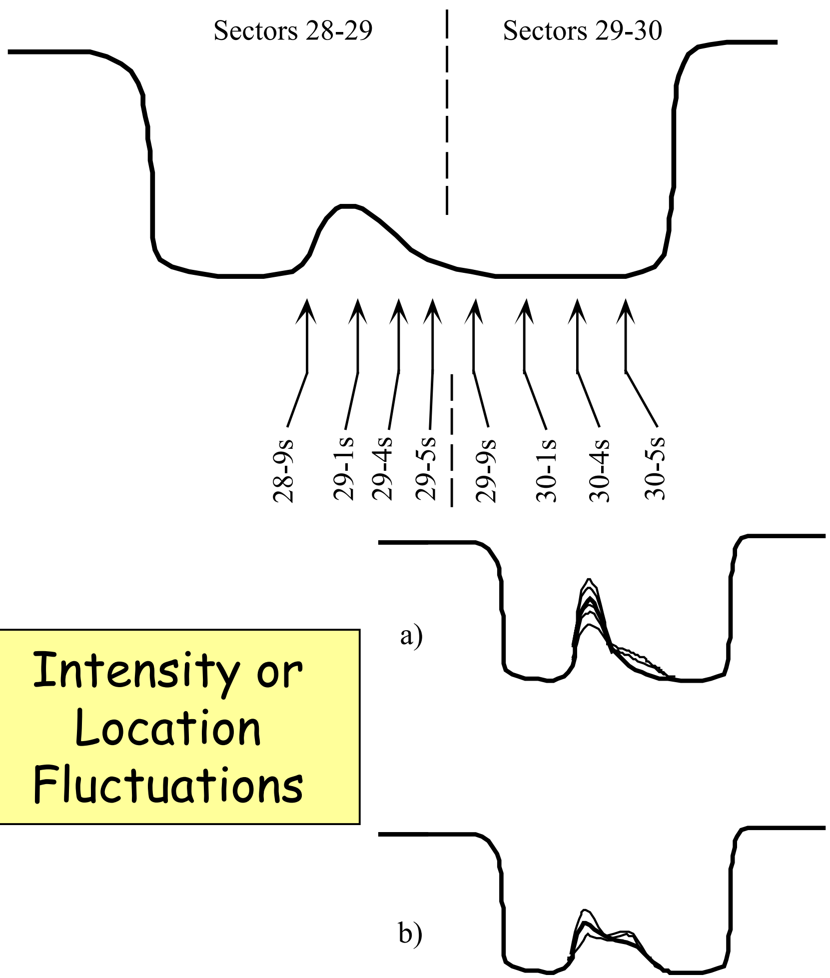


SR Fans from Halo in Final Focus



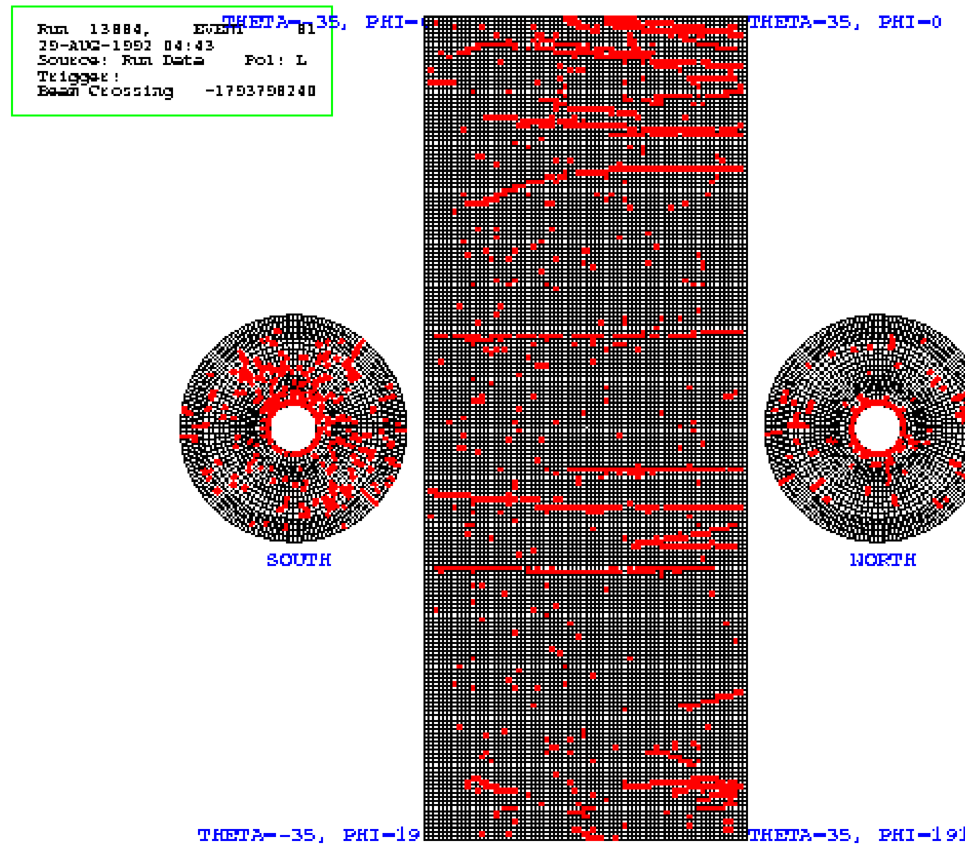
Muons in SLD

Linear Ion Chamber: Losses in Collimators



Intensity or Location Fluctuations

Muons from Collimators in EM Calorimeters



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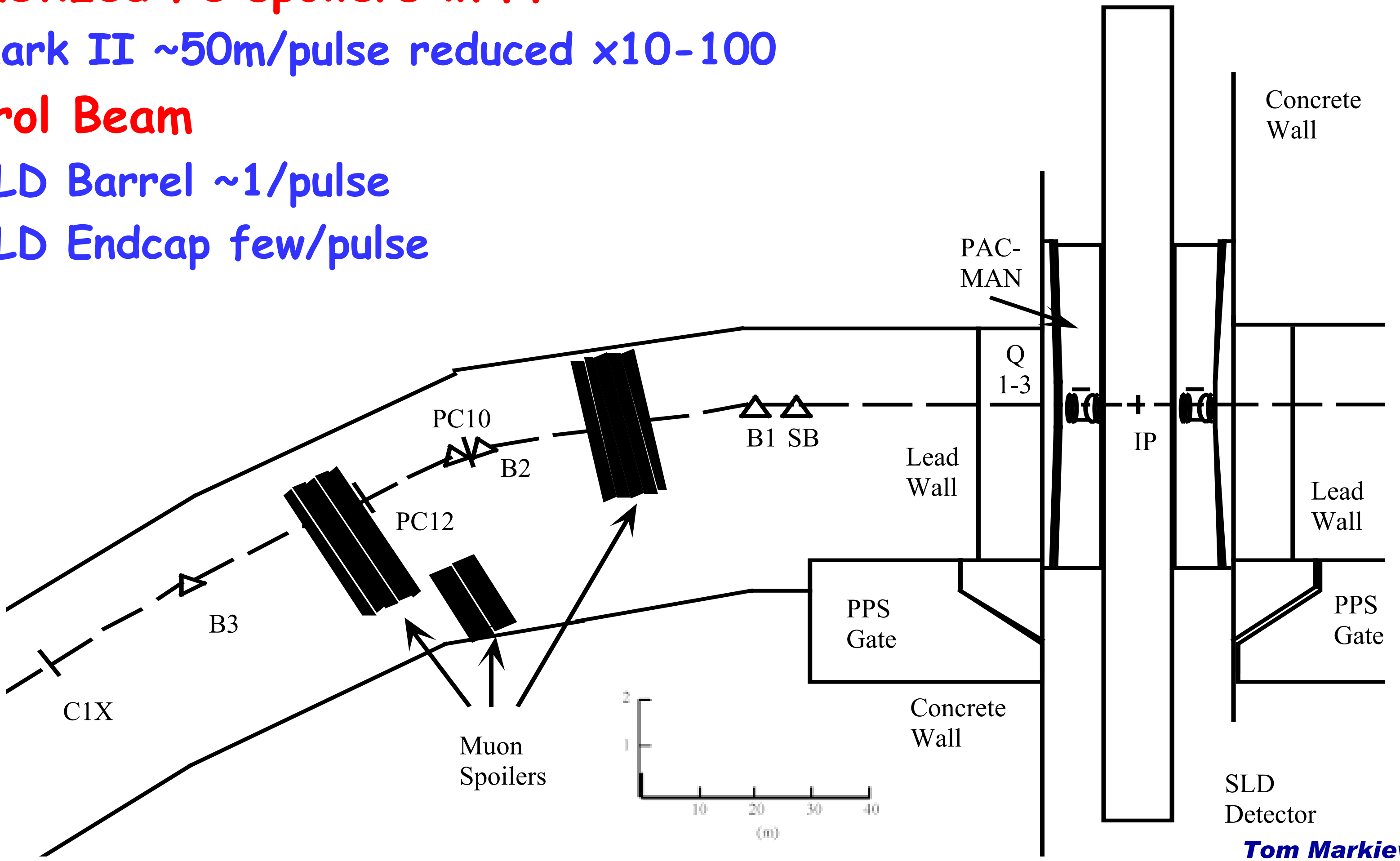
SLC Muon Solutions

- Move primary collimators to linac
- Magnetized Fe spoilers in FF
  - Mark II ~50m/pulse reduced x10-100
- Control Beam
  - SLD Barrel ~1/pulse
  - SLD Endcap few/pulse



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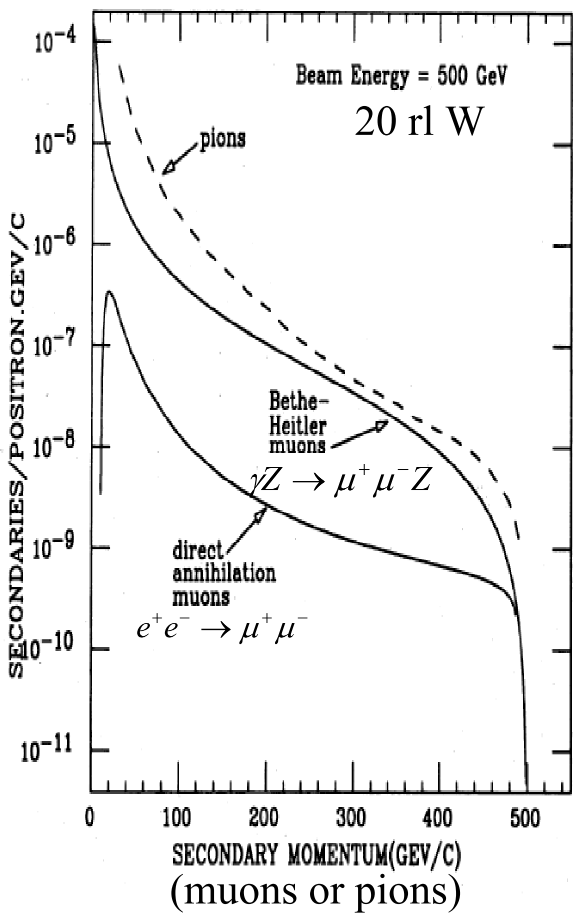
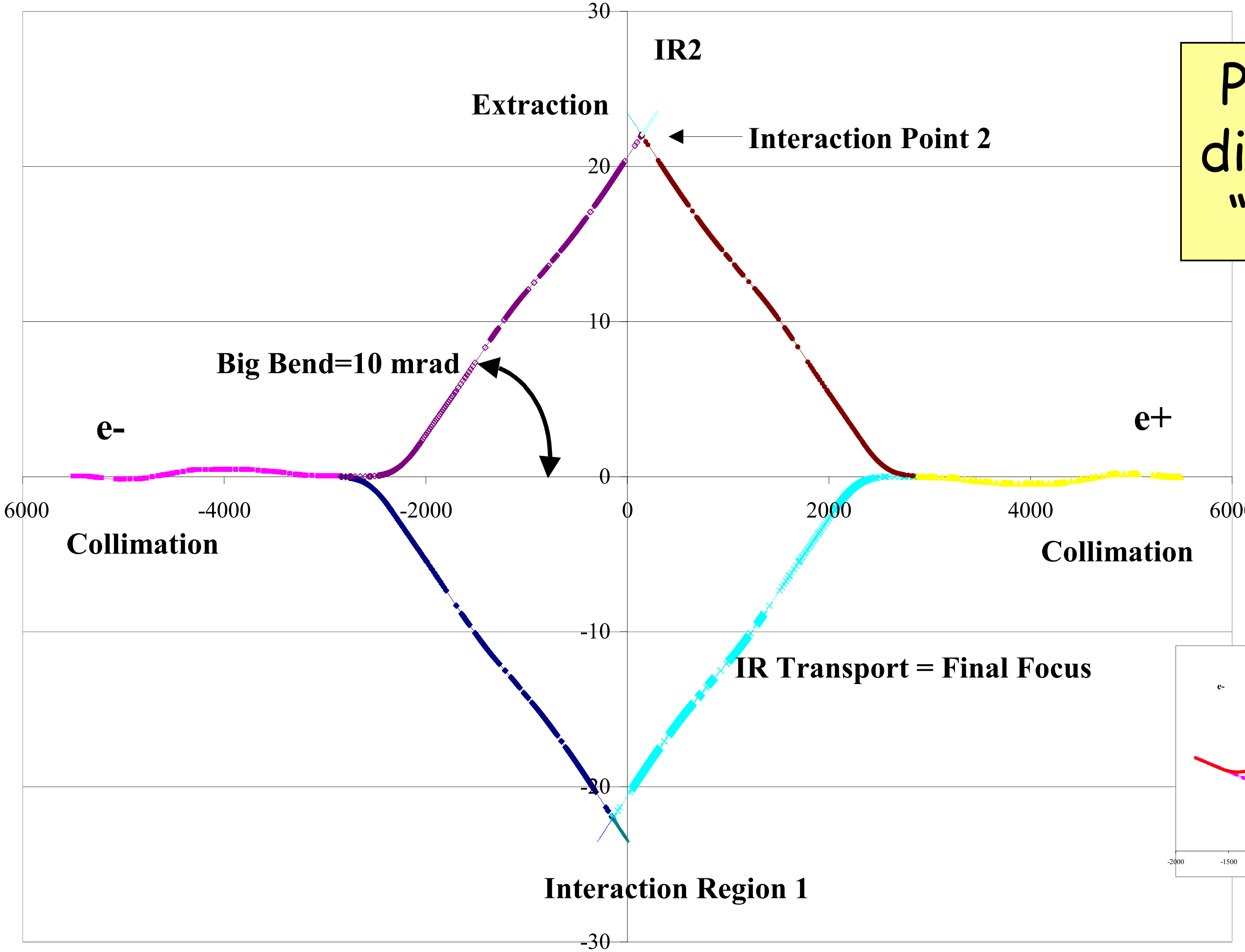
MUCARLO Muon Transport Program



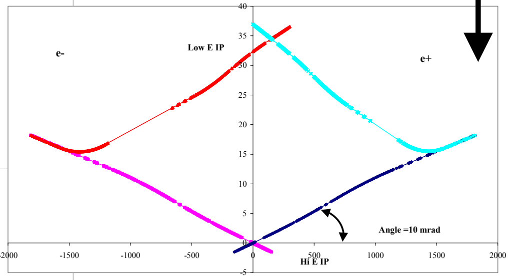
- Written by G. Feldman for MarkII & extensively used/modified by Lew Keller
- Step-by-step transport with MCS & dE/dx, $\mu Z \rightarrow \mu Z\gamma$, $\mu Z \rightarrow \mu Ze+e-$, & $\mu N \rightarrow \underline{\mu}X$
- Geometry extensively modeled
  - magnets w/poles, coils & flux return
  - Tunnels with concrete, dirt, Pb, air, steel…
- Basic production mechanism: Bethe-Heitler in "Thick-Target Approx"
  - Thin targets, direct annihilation require separate EGS runs
  - Pions not included
    - Long decay lengths
    - Assumed will interact in a filled tunnel
- Benchmarked against Muon89 (Ralph Nelson/SLAC ES&H) & Mark II data
  - Await comparison with MARS & GEANT4

NLC Beam Delivery thru 1999

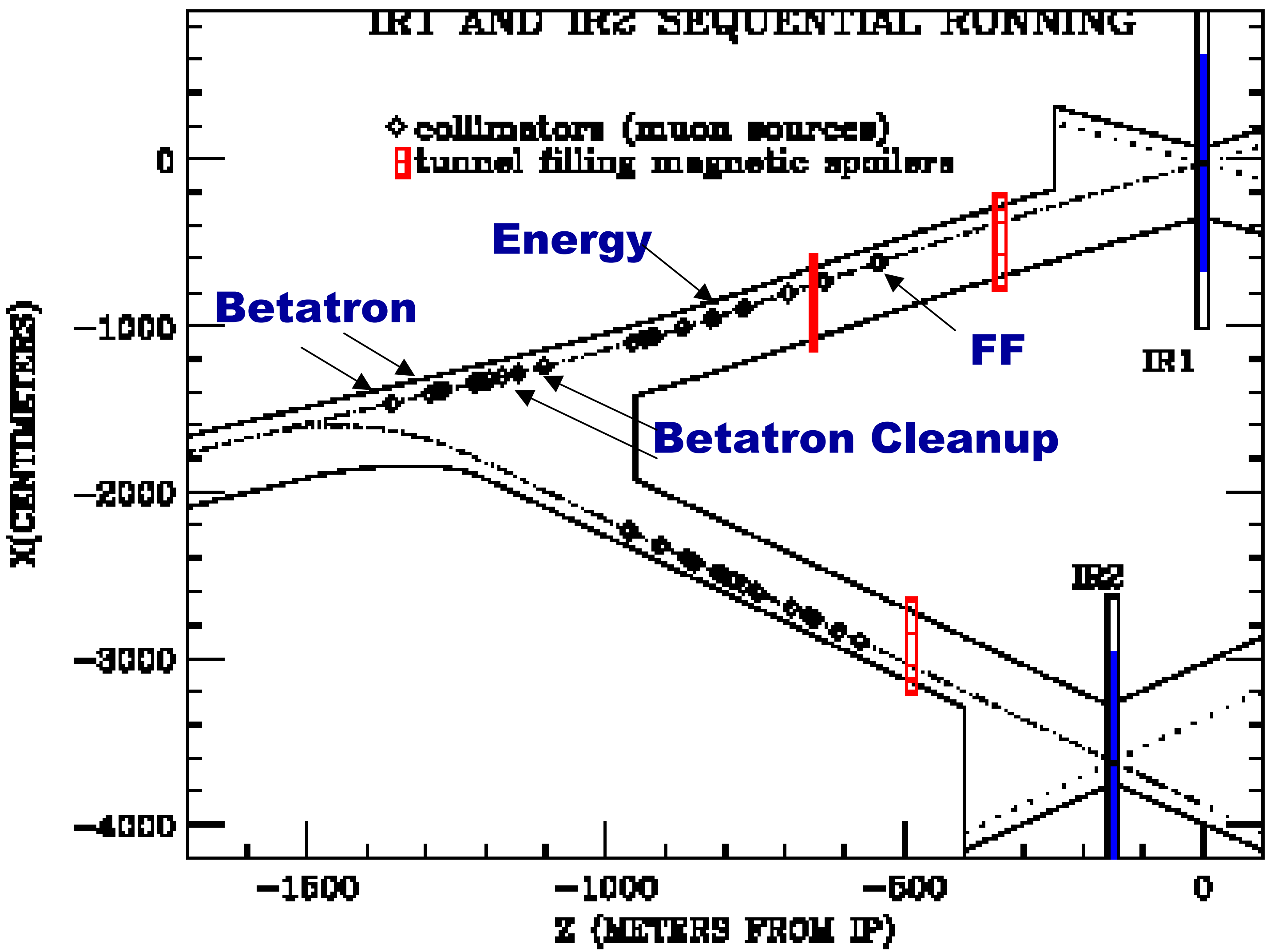


Protect via distance and "Big Bend"

Currently 3x shorter & No Bend



Layout of Spoilers, Absorbers & Protection Collimators



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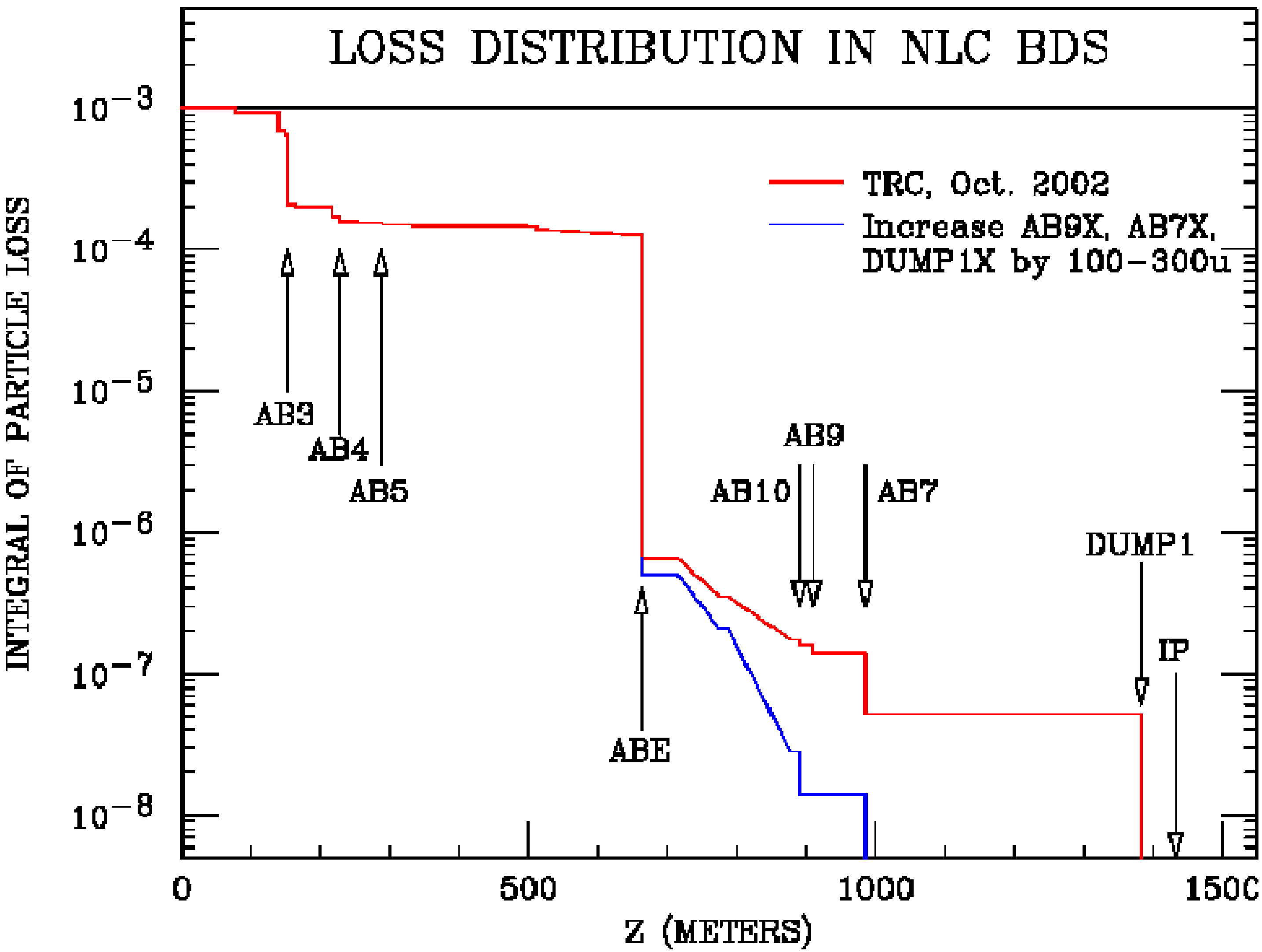
Efficiency of NLC Collimation System (Talk by Andrei Seryi)

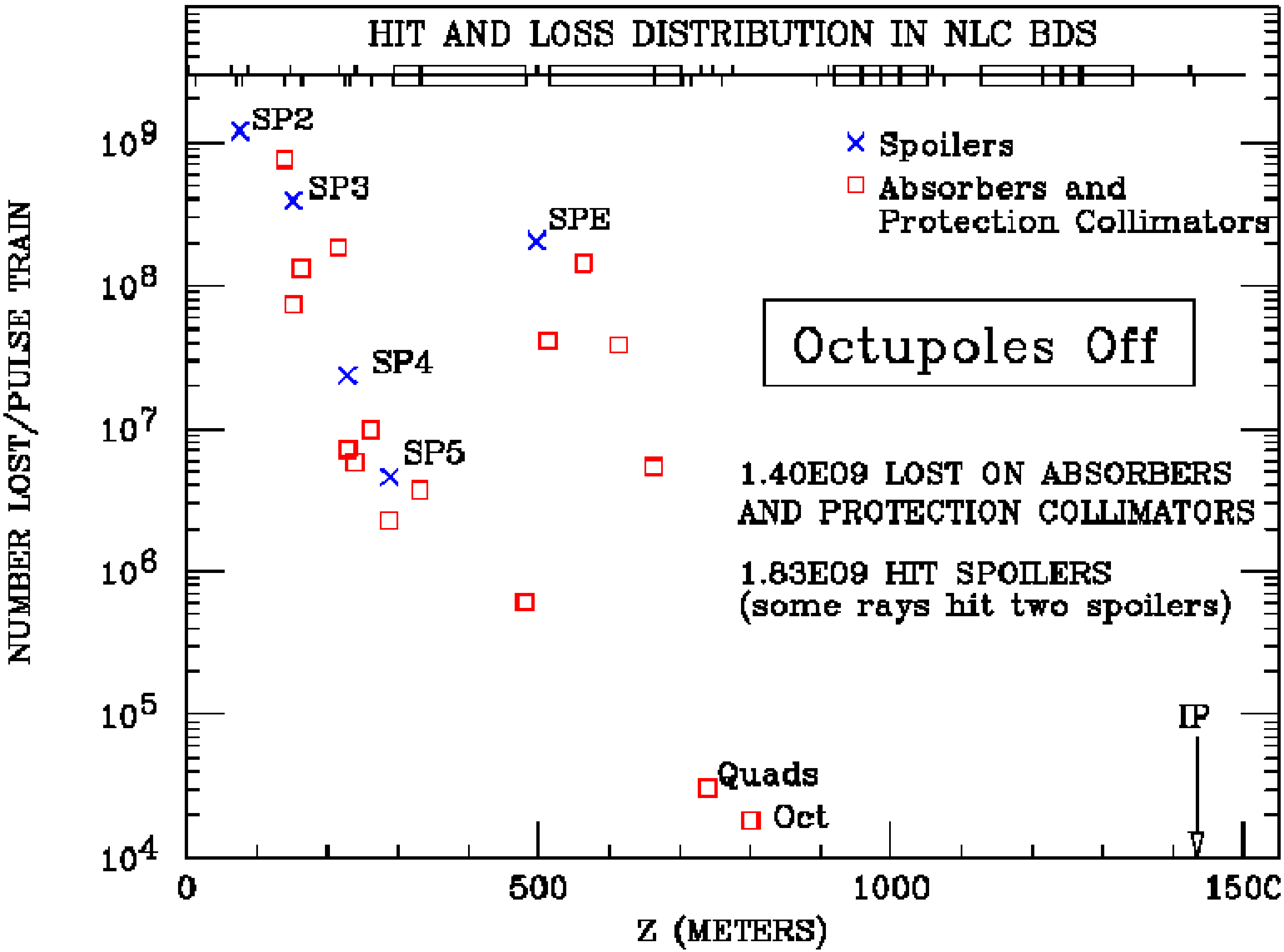


E=250 GeV

N=1.4E12

0.1% Halo distributed as 1/X and 1/Y for $6<A_x<16\sigma_x$ and $24<A_y<73\sigma_y$ with $\Delta p/p=0.01$ gaussian distributed

Calculated Beam Loss: Input to MuCarlo



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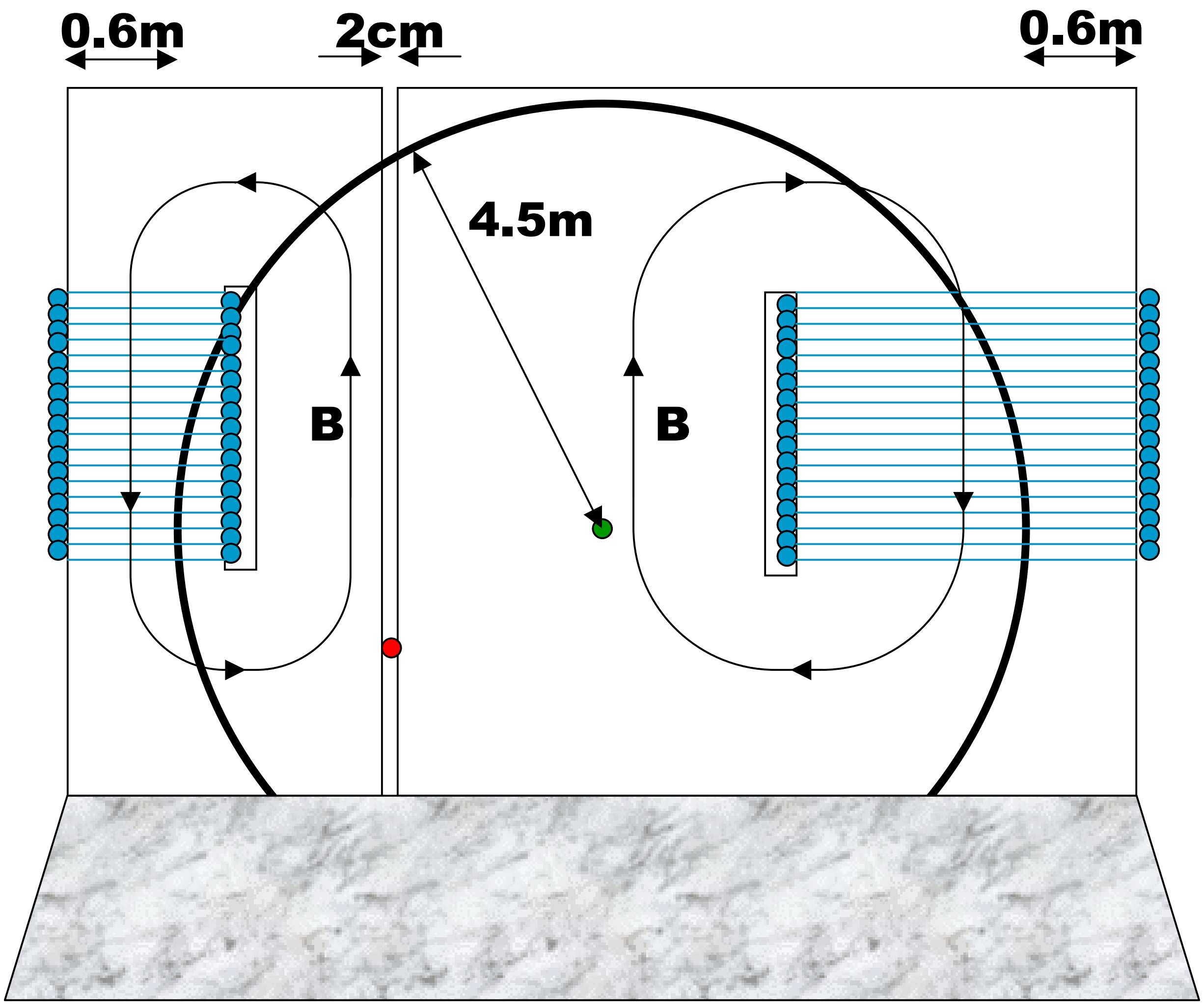
9 & 18m Toroid Spoiler Walls



170 Tons/m

Design Constraints: Minimize gap & minimize stray field in beampipe

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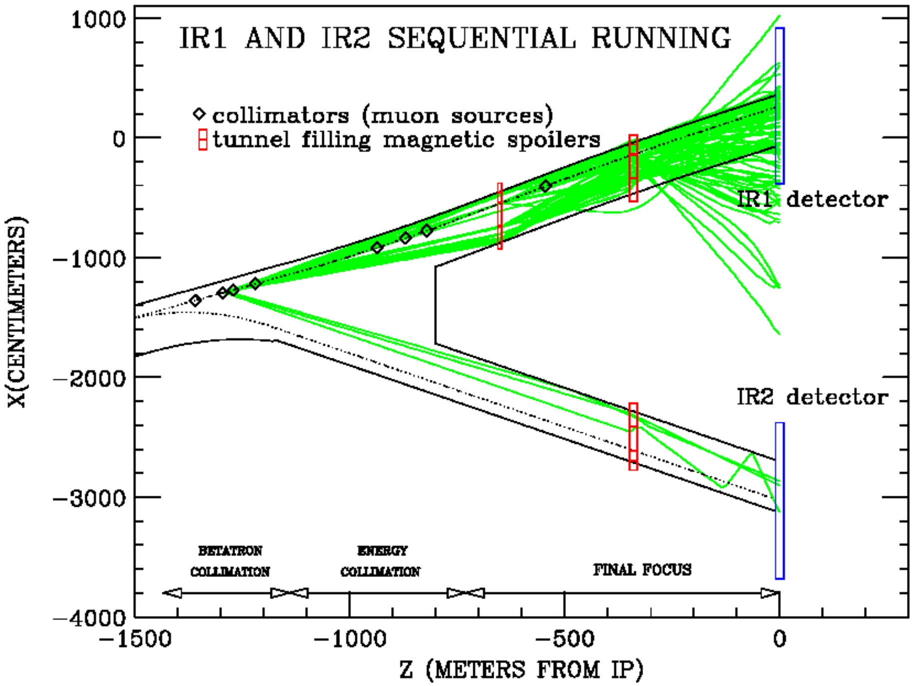
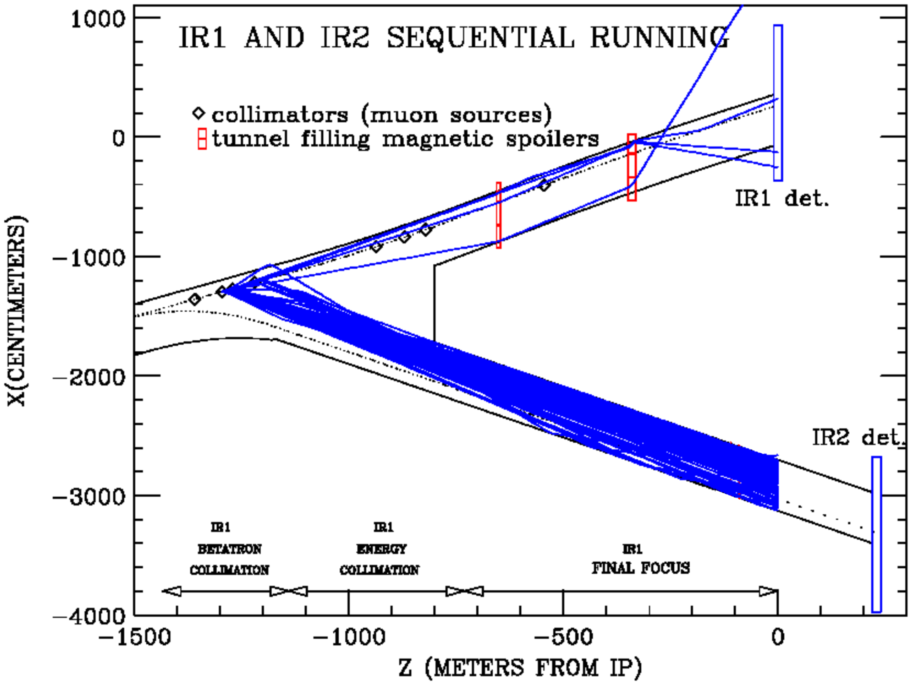
First 100 Muons from PC1 of HEIR beamline that reach z=0
IR1 line has 9m & 18m magnetized walls

Somewhat arbitrary Goal: 10 muons / detector / train
(from both e-,e+ systems)

IR2 line has 18m wall



NO 18m wall in IR2 line



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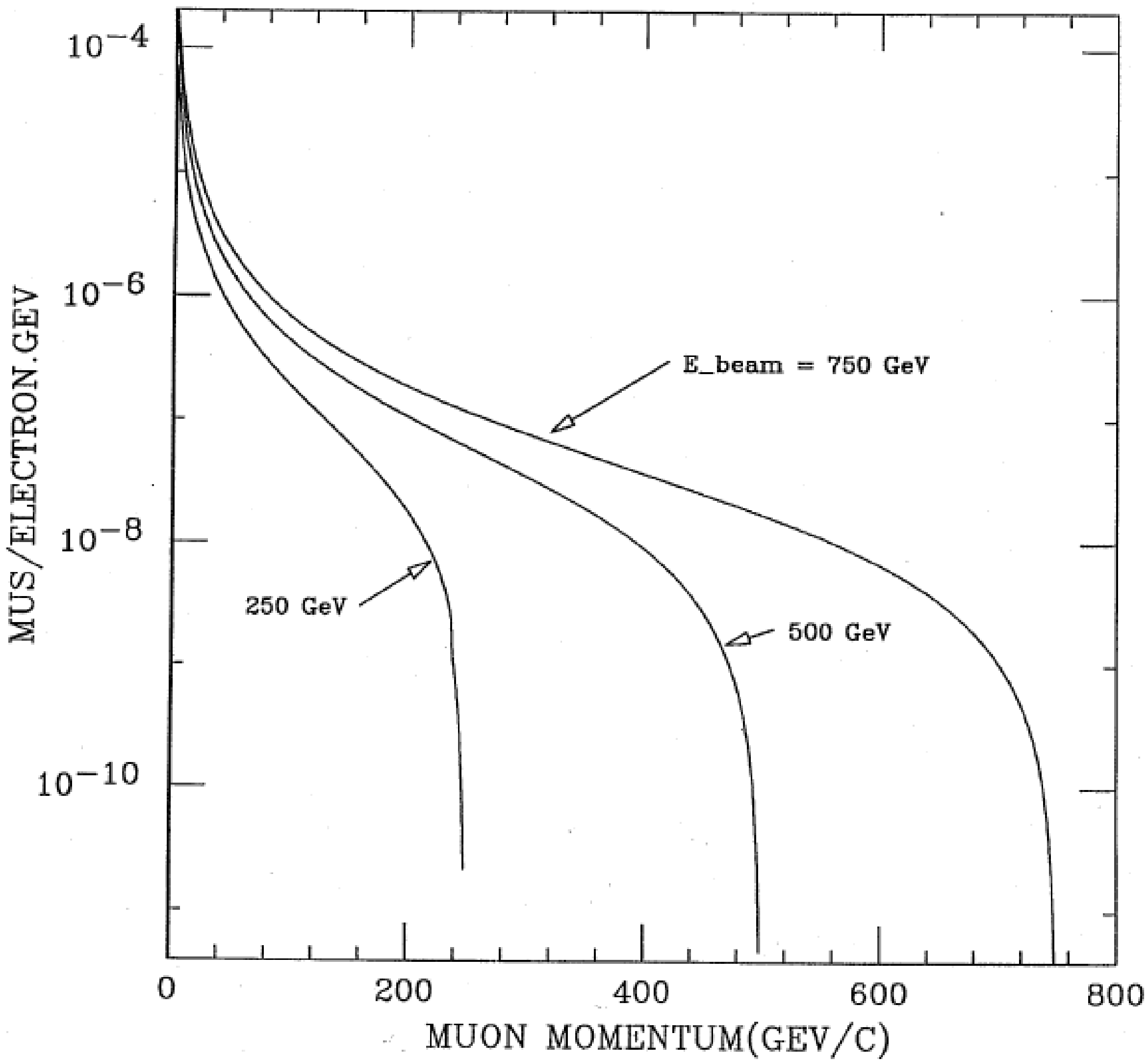
Muon Yield



For 250 GeV
p_μ>1 GeV/c

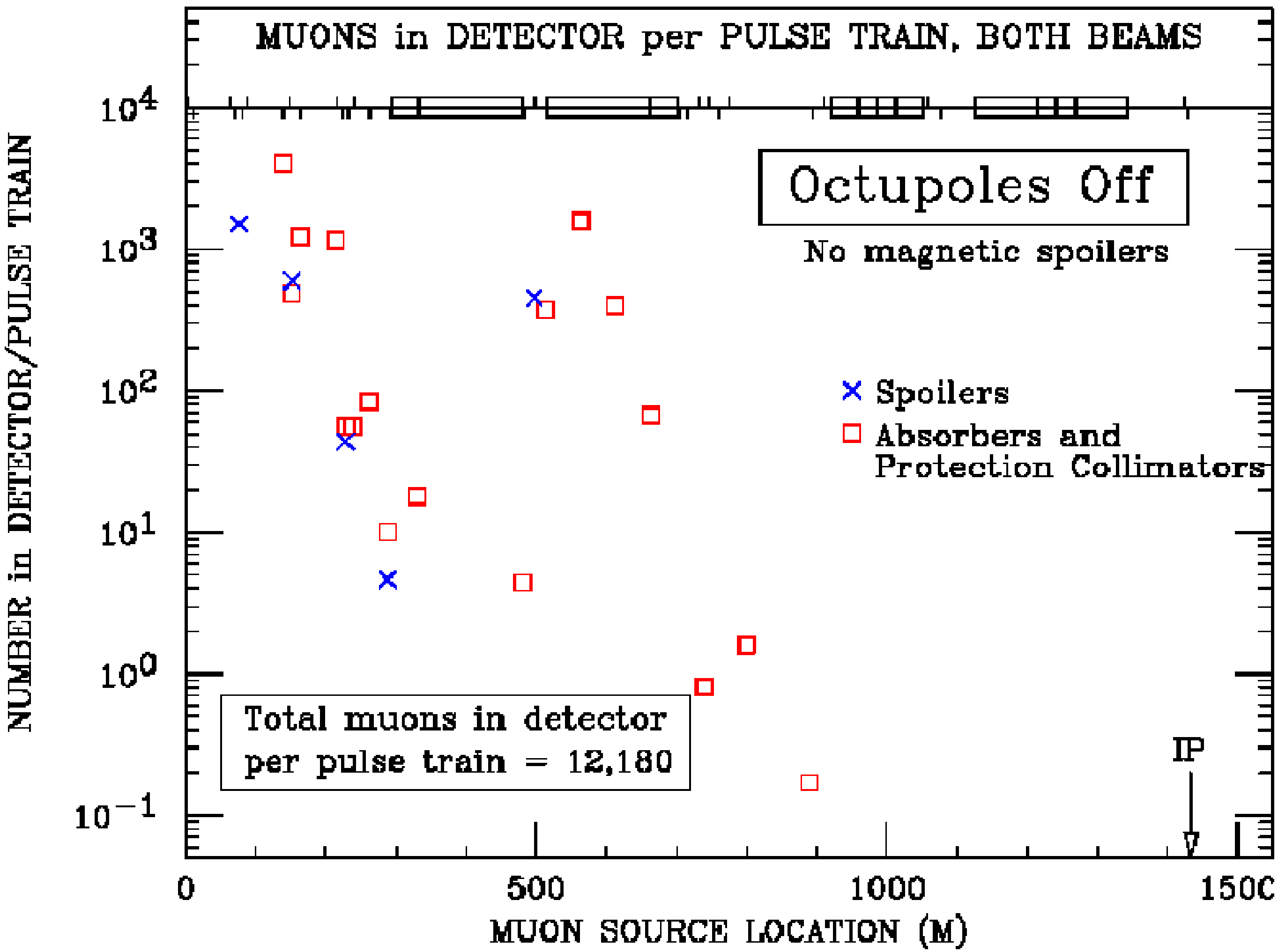
$\mu/e = 5 \times 10^{-4}$

Yield scales with beam energy

Muon rate in detector ~1000x design goal before adding spoiler walls

** Assumed Halo 1E-3

4.4E-6 Muons/Scraped e-



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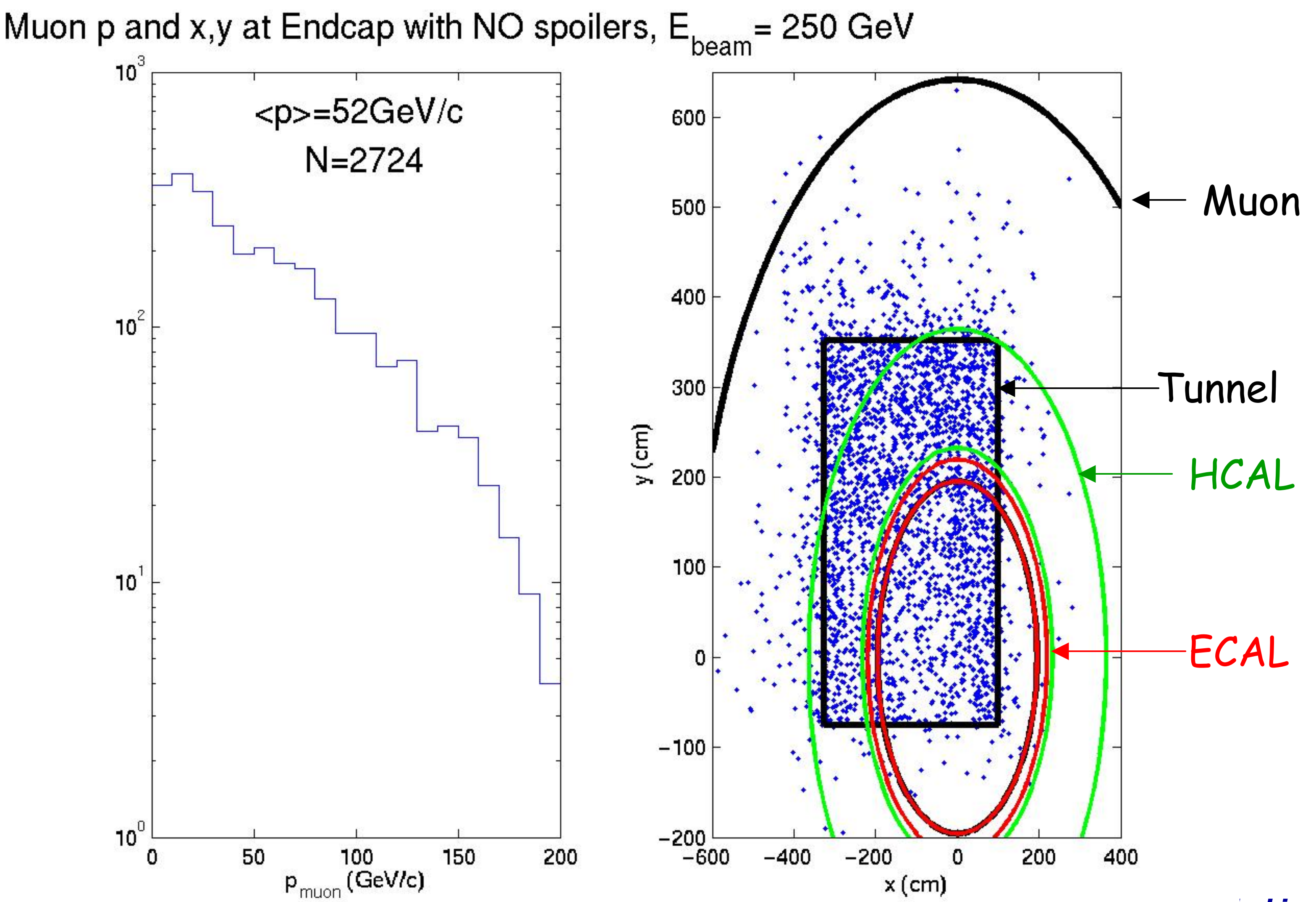
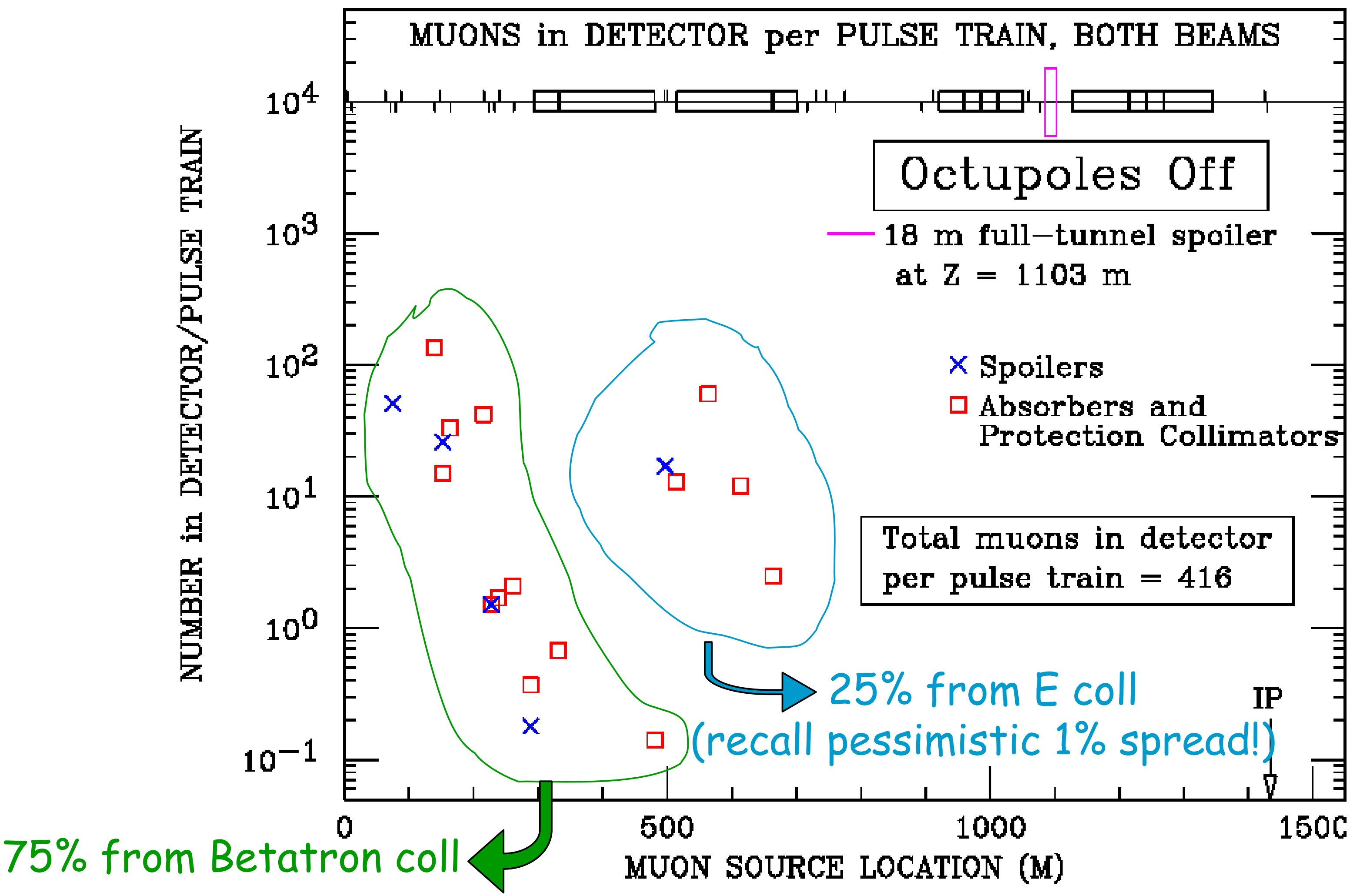
Distributions with No Spoilers at 250 Gev/ Beam



18m Wall Downbeam of all sources reduces rate by x30



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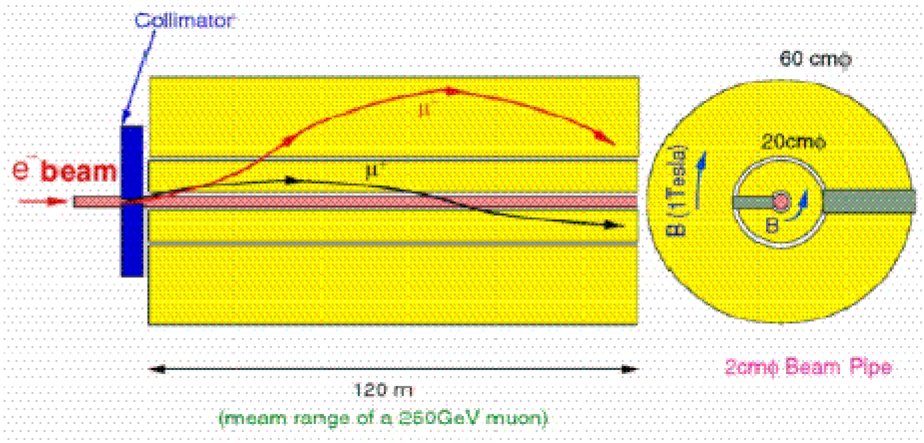
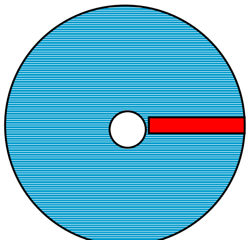
Donut Toroid Muon Attenuators



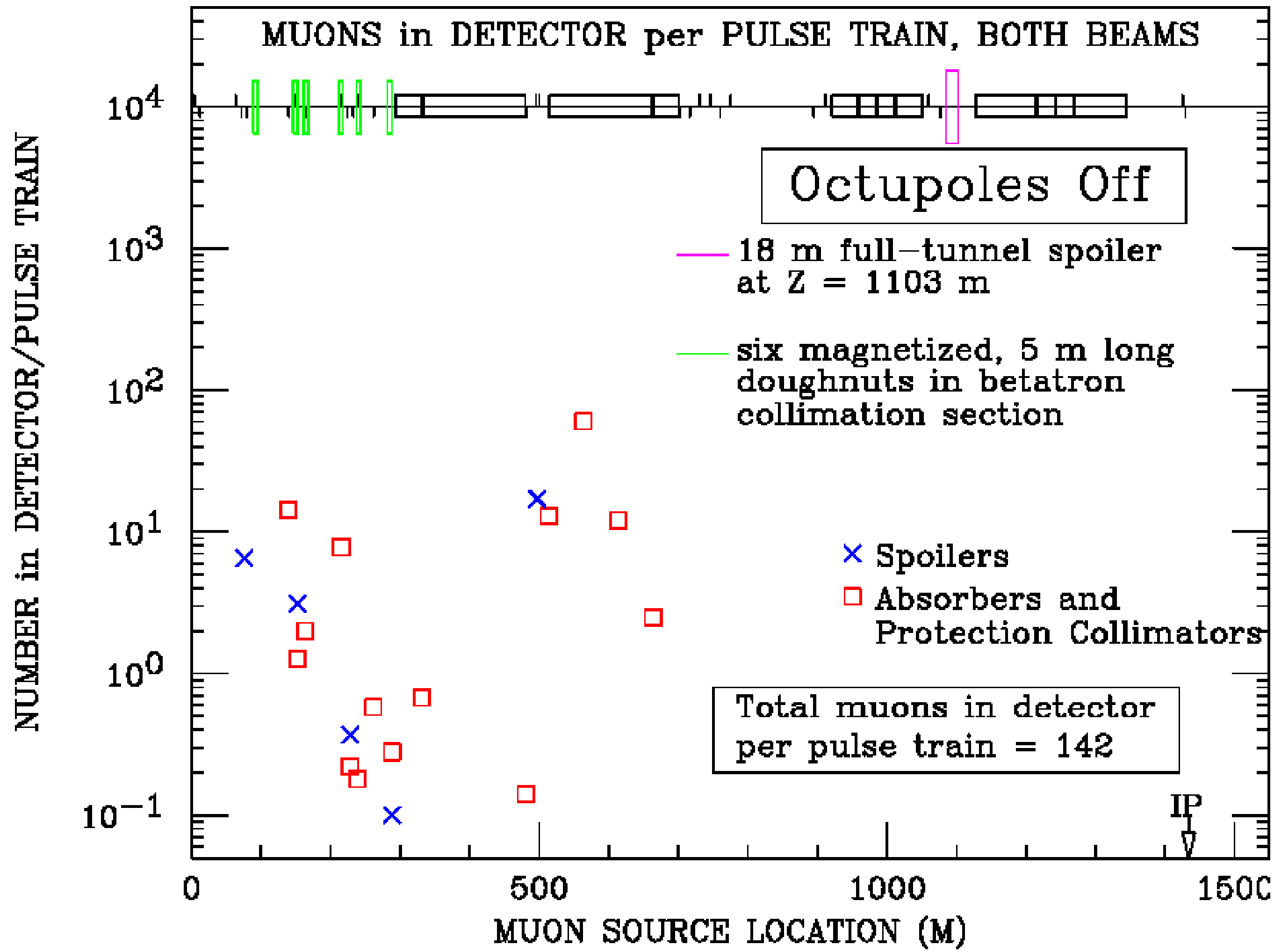
JLC advocates double donut

TESLA uses single donut

- Well defined source locations followed by at least 5m of free space (at 250 GeV/beam) may be serviced by devoted attenuators
  - Nice if there is a dipole between the source and the donut
- Lattice does not always permit this
  - NLC betatron collimation system has space for 6 5m-long attenuators (SP2/AB2,PC1,SP3/AB3/PC2,PC3,SP4/AB4/PC4,PC5/SP5/AB5)
  - NLC energy collimation region has no space
- NLC MuCarlo study uses 120cm diameter donut toroids



Donuts reduce Muon rate from Betatron Region rate by x8



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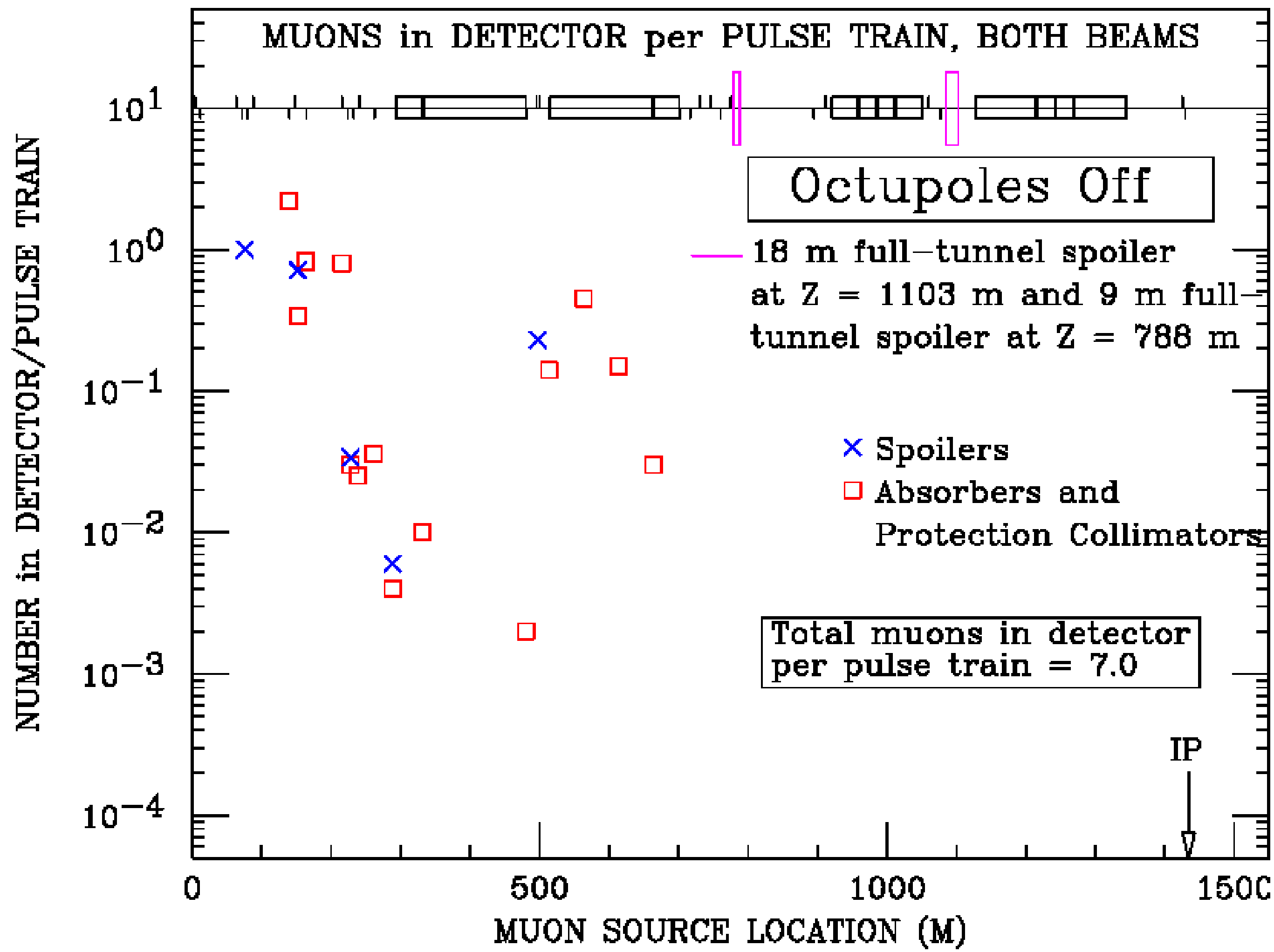
Additional 9m Wall reduces Betatron μ rate by x50 and E Coll μ rate by x100



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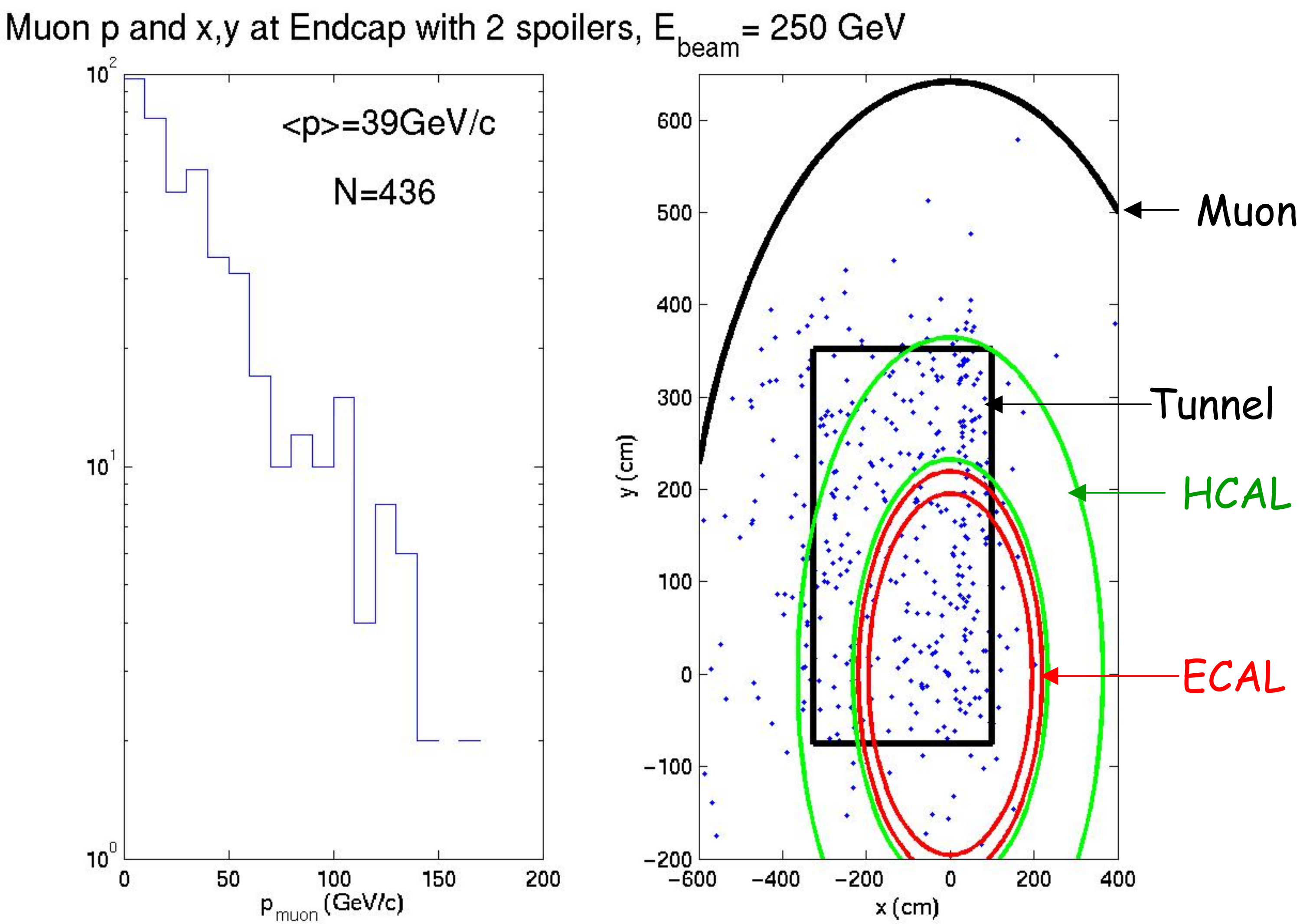
Distributions with 2 Spoilers at 250 Gev/ Beam



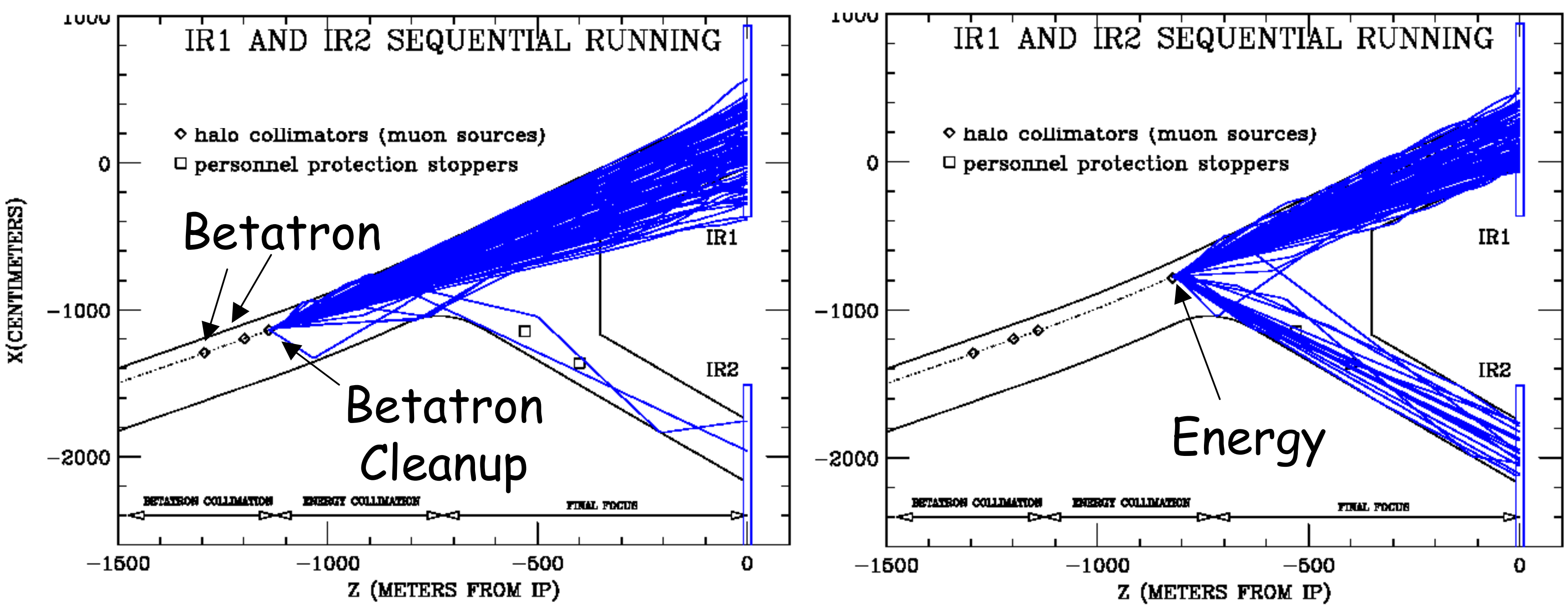
Radiation Safety Aspect of Collimator System Muons

- Can you occupy IR2 when IR1 is running?
- Can you occupy IR1 when IR2 is running?

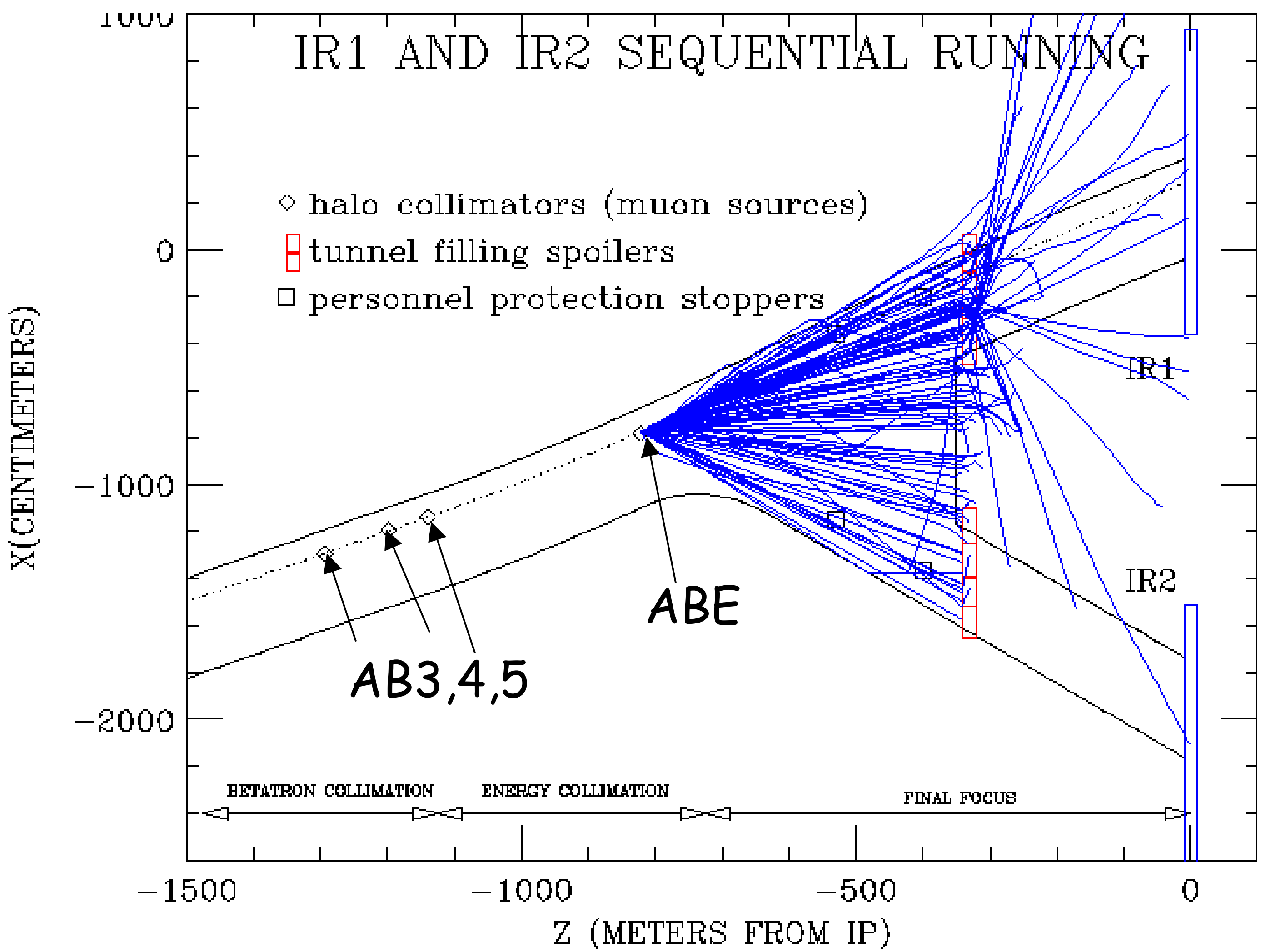
Shorter COLL/FF makes this more difficult than before

Last studied for 2001 BD model with shared collimation

But as long as IR2 “sees” IR1 collimators issue will remain



Simultaneous Occupation Permitted If Magnetized Wall Is Present



2001 Rad Safety Dose Rate Analysis

- Use current lattice to IR1
- Tunnel to IR2 holds just FF2
  - Not important; need to iterate; worse case
- Run both 250 and 500 GeV beams with full charge (1.7E14e-/sec) and assume 0.1% Halo
- Muon Source Terms on Collimators
  - 1st stage Betatron: 0.1% e- make muons
  - 2nd stage Betatron: 0.01% e- make muons
  - E-slit: 0.01% e- make muons
- SLAC Rad Safety Rules:
  - 0.5 mrem/hr for normal operation
  - 25 rem/hr (3 rem max dose) for max credible accident
- Run MUCARLO and find maximum dose rate in any 80cmx80cm area

Muon Dose Rates in IR1 and IR2 when other IR has beam

1.0 TeV CM		No Spoiler		18m Mag Spoiler @ z=321m	
Source	Halo	IR1 (mr/hr)	IR2 (mr/hr)	IR1 (mr/hr)	IR2 (mr/hr)
AB3@1294m	10^{-3}	2.54	0.016	0.015	0.070
AB4@1198m	10^{-3}	2.45	0.041	0.13	0.71
AB5@1140m	10^{-4}	0.12	0.005	0.011	0.002
ABE@822m	10^{-4}	0.34	0.082	0.013	0.007
Total for 2 beams		10.9	0.29	0.61	0.15
Total for 2 beams @500 GeV		4.5	0.13	0.12	0.01

- If do nothing and halo=10^{-3}, dose is 10-20x SLAC 0.5 mrem limit
- 18m mag spoiler buys you x20 to 40; IR2 looks OK in any event
- Max credible accident only dumps 10^3 more beam, limit is 50E3 higher

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Conclusions

- Unless the beam halo loss rate is ~10^{-6}, all collimator designs will need some combination of magnetized spoilers to reduce the muon flux
- For the case of the NLC design it appears that two magnetized walls serve the purpose.
- At least one wall per IR per side may be required for personnel protection
- Current plan is to leave space for the caverns that would enclose these walls but to not install until measurements of halo and muon production sources indicate it is necessary.
- Judicious use of point muon attenuators may be useful